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DIRECT MEASUREMENTS OF INTERPLANETARY DUST PARTICLES IN THE VICINITY OF EARTH

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Washington, D. C.

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SUMMARY

The direct measurements made by the Explorer VIII satellite provide the first sound basis for analyzing all available direct measurements of the distribution of interplanetary dust particles. The model average distribution curve established by such an analysis departs significantly from that predicted by the (uncertain) extrapolation of results from meteor observations. A consequence of this difference is that the daily accretion of interplanetary particulate matter by the earth is now considered to be mainly dust particles of the direct measurements range of particle size. Almost all the available direct measurements obtained with microphone systems on rockets, satellites, and spacecraft fit directly on the distribution curve defined by Explorer VIII data. The lack of reliable datum points departing significantly from the model average distribution curve means that available direct measurements show no discernible evidence of an appreciable geocentric concentration of interplanetary dust particles.

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INTRODUCTION

Direct measurements by rockets, satellites, and space probes have contributed much to the knowledge of interplanetary dust particles. Such data have already been discussed in connection with the microphone type of dust particle sensor carried by the U. S. satellites Explorer I (1958 α) and Vanguard III (1959 η); the U. S. space probe Pioneer I; the Soviet satellite Sputnik III (1958 δ_2); the Soviet Space Rockets I and II; and the Soviet Interplanetary Station (1959 θ). A definitive set of data has recently been obtained with a microphone system on the U. S. satellite Explorer VIII (1960 ξ). Furthermore, results from successful high-altitude rockets, instrumented at Oklahoma State University (OSU), can be used in quantitative discussions of interplanetary dust particles, if the proper corrections are applied. This paper presents the preliminary results derived from an analysis of the data which have been obtained.

THE MICROPHONE SYSTEM

The best calibrations of the microphone system presently possible are those performed with particles ranging from large glass beads elastically impacting at low speeds to small iron spheres inelastically impacting at speeds up to approximately 10 km/sec. Such calibrations indicate that the microphone system is sensitive to a quantity that is closely related to the momentum of an impacting dust particle. An average velocity of 30 km/sec, relative to a satellite, has been assigned to the dust particles in order that the data may be used to determine the average mass distribution of interplanetary dust particles.

*This paper is an abridged version of a "Letter to the Editor" published in Nature.

THE DISTRIBUTION CURVE FOR INTERPLANETARY DUST PARTICLES

The three datum points obtained with Explorer VIII, and those from Vanguard III, Explorer I, and the OSU rocket series, are plotted as a distribution curve in Figure 1. The equation of the straight line that approximately fits the datum points is:

$$\log I = -17.0 - 1.70 \log m,$$

where I is the influx rate of dust particles and m is the particle mass. The equation is approximately true for m in the range between 10^{-10} and 10^{-6} gm. The data from Vanguard III, Explorer I, and the rockets fit remarkably well onto the curve defined by the data from Explorer VIII. In fact, all available direct measurements can be made to fit reasonally well onto this curve, if proper allowances are made for; (a) the type of experiment; (b) the confidence that can be placed in the measurements; (c) the shielding effect of the earth; and (d) the actual fluctuations in spatial density as observed by Explorer I, Vanguard III, and Explorer VIII.

Figure 1 also contains two reference lines which represent the results of meteor observations. They were obtained from an extrapolation of the tabulation by Watson (Reference 1) and from the extrapolated tabulation by Whipple (Reference 2). Both of these lines follow the constant-mass-per-unit-visual-magnitude relationship common to the discussions of results of meteor observations. They roughly serve as the limits of uncertainty for placing such results on a mass distribution curve. This uncertainty arises because of the uncertainty in relating the mass of the particle to its photographic, visual, and radar magnitudes, and because of the uncertainty in assigning a mass density to meteoroidal particles.

Either of the extrapolated curves can be forced to pass through any given direct measurements datum point merely by adjusting the mass-to-magnitude relationships and the mass density of meteoroidal particles. Since the three datum points obtained with Explorer VIII define the influx rates for dust particles in three different ranges of particle mass, they also can be used to define a slope for a limited portion of the distribution curve. The curve so determined departs significantly from the extrapolated curves.

Caution must be exercised in extrapolating the new distribution curve (Figure 1) beyond the range of particle mass for which direct measurements have actually been obtained. There will be a considerable difference between the shape of the distribution curve in the direct measurements range of particle size and its shape in the range of size where radiation pressure control is dominant, unless there is a most prolific source of very small dust particles somewhere near or inside the earth's orbit. This new distribution curve can be joined smoothly to the Watson curve when the size

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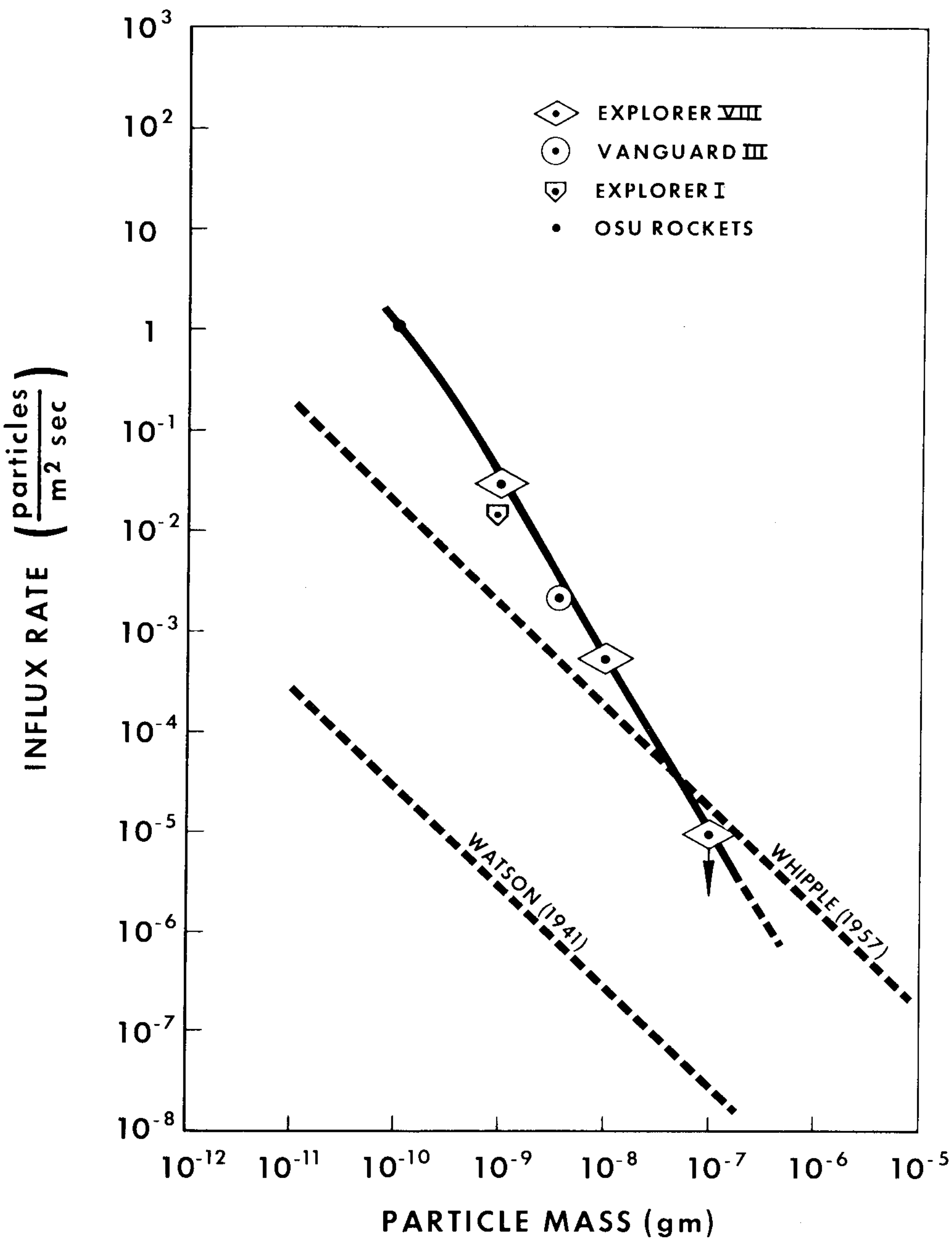

Figure 1 – Distribution curve for interplanetary dust particles in the vicinity of earth

of the particle is smaller than the faintest radar meteors, but junction with the Whipple curve is rather difficult.

An interesting fact shown by the new distribution curve is that the daily influx rate of interplanetary dust is approximately 10^4 tons per day on the earth. This means that dust particles in the direct measurements range of particle size dominate the earth's accretion process. Further investigation must be made in order to determine the meaning of the

new distribution curve in regard to theories of the zodiacal light and observations of atmospheric aerosols.

COMPARISON OF RESULTS

Prior to the use of Explorer VIII, the question of whether the direct measurements data show that the spatial density of dust particles has an altitude dependence could not be resolved by using results obtained with the microphone type of impact detector. The reason for this was that the rocket measurements were of high sensitivity and were made at low altitudes whereas reliable satellite measurements were generally of low sensitivity and at high altitudes. Pioneer I made measurements of high sensitivity at a large geocentric distance, but these extended over only a short sampling interval and may not be of much use in establishing a model average distribution. Any one of several interpretations could be given to the available direct measurements, depending on the choice of a model distribution to which they were compared.

By assuming that the Whipple curve (Figure 1) represented the true distribution, Whipple (Reference 3) has deduced that direct measurements confirm the existence of a geocentric "dust belt". If the empirical curve defined by the data from Explorer VIII is a correct basis upon which to analyze other direct measurements results, then the spatial density of dust particles has no discernible altitude dependence. The conjectural geocentric concentration of dust particles under discussion here should not be confused with concentrations of dust particles possibly suspended in the earth's atmosphere at and slightly above the temperature inversion layer (about 80 km altitude).

CONCLUSION

It should be emphasized that although the presently available data show no evidence for the existence of an appreciable geocentric concentration of dust particles, the data really are not of such a nature that they can conclusively settle the question. If such a concentration does exist, it certainly has not been convincingly measured by rockets and satellites. The direct measurements are quite useful in determining a model for the average dust distribution and, when displayed as in Figure 1, the results of such measurements show remarkable consistency.

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